# Unit 5: Bonding and Inorganic Nomenclature

## Chemical Bonding

- ***Ionic Bonds***: atoms give up or gain $e^-$ and are attracted to each other by coulombic attraction

Na loses an $e^-$

$Na \rightarrow Na^{1+} + e^-$

Cl gains an $e^-$

$Cl + e^- \rightarrow Cl^{1-}$

ionic compounds = salts

$Na^{1+} + Cl^{1-} \rightarrow NaCl$

$K^{1+} + NO_3^{1-} \rightarrow KNO_3$

where $NO_3^{1-}$ is a polyatomic ion: a charged group of atoms that stay together

***Properties of Salts***

1. very hard – each ion is bonded to several oppositely-charged ions
2. high melting points – many bonds must be broken
3. brittle – with sufficient force, like atoms are brought next to each other and repel

- ***Covalent Bonds***

…atoms share e$^-$ to get a full valence shell

C  $1s^2\ 2s^2\ 2p^2$  (4 v.e$^-$)

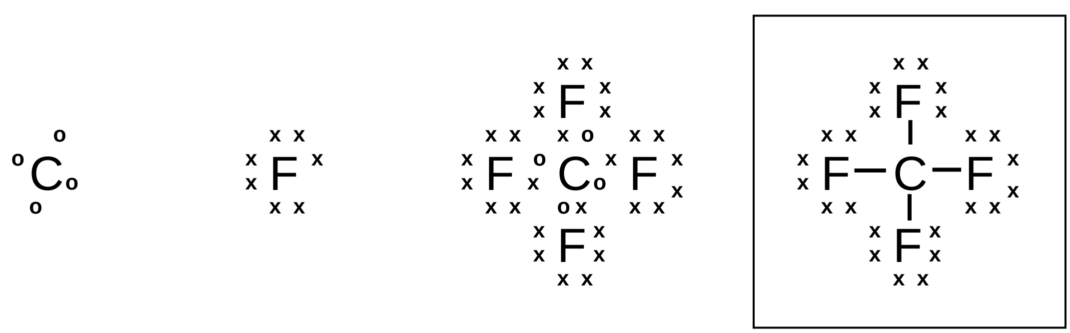
F  $1s^2\ 2s^2\ 2p^5$  (7 v.e$^-$)

both need 8 v.e$^-$ for a full outer shell (<u>octet rule</u>)

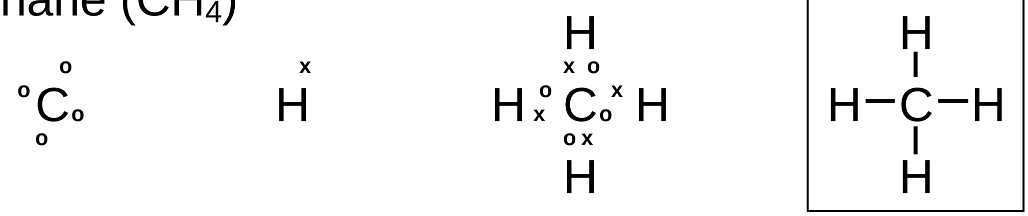
<u>Lewis structure</u>: a model of a covalent molecule that shows all of the valence e$^-$

1. Two shared e$^-$ make a single covalent bond, four make a double bond, etc.
2. <u>unshared pairs</u>: pairs of unbonded valence e$^-$
3. Each atom needs a full outer shell, i.e., 8 e$^-$. Exception: H needs 2 e$^-$

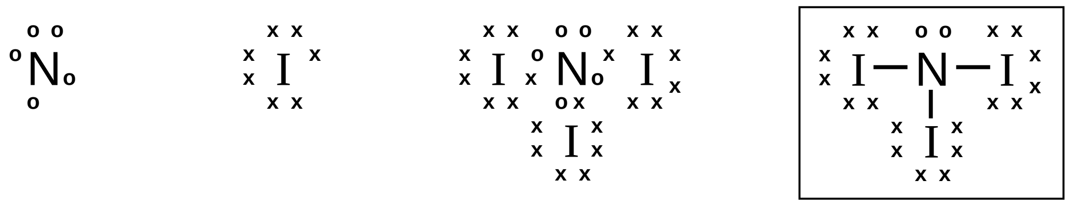
carbon tetrafluoride ($CF_4$)



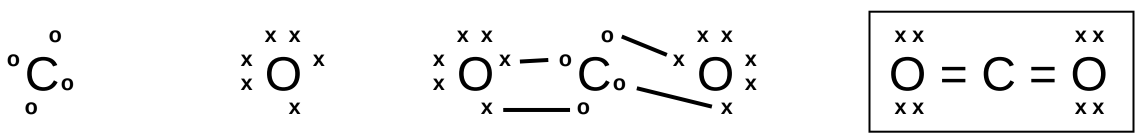
methane ($CH_4$)



nitrogen triiodide ($NI_3$)



carbon dioxide ($CO_2$)



<u>covalent compounds</u> = <u>molecular compounds</u>

-- have lower melting points than do ionic compounds

- ***Metallic Bonds***

In metals, valence shells of atoms overlap, so v.e$^-$ are free to travel between atoms through material

***Properties of Metals***

conduct heat and electricity; ductile; malleable

- ***Other Types of Bonds***

dipole-dipole forces, hydrogen bonds, London dispersion forces; & ion-dipole forces (solutions)

# Writing Formulas of Ionic Compounds

chemical formula: has neutral charge;

shows types of atoms and how many of each

To write an ionic compound's formula, we need:

1. the two types of ions
2. the charge on each ion

| | | | |
|---|---|---|---|
| $Na^{1+}$ | and | $F^{1-}$ | NaF |
| $Ba^{2+}$ | and | $O^{2-}$ | BaO |
| $Na^{1+}$ | and | $O^{2-}$ | $Na_2O$ |
| $Ba^{2+}$ | and | $F^{1-}$ | $BaF_2$ |

criss-cross rule: charge on $\boxed{\text{cation}}$ / anion

"becomes" subscript of $\boxed{\text{anion}}$ / cation

** Warning: Reduce to lowest terms.

$Al^{3+}$ and $O^{2-}$ → $Al_2\,O_3$ → $\boxed{Al_2O_3}$

$Ba^{2+}$ and $S^{2-}$ → $Ba_2\,S_2$ → $\boxed{BaS}$

$In^{3+}$ and $Br^{1-}$ → $In_1\,Br_3$ → $\boxed{InBr_3}$

## ❑ *Writing Formulas ^w/Polyatomic Ions*

Parentheses are required only when you need more than one "bunch" of a particular polyatomic ion.

| | | | |
|---|---|---|---|
| $Ba^{2+}$ | and | $SO_4^{2-}$ | $\boxed{BaSO_4}$ |
| $Mg^{2+}$ | and | $NO_2^{1-}$ | $\boxed{Mg(NO_2)_2}$ |
| $NH_4^{1+}$ | and | $ClO_3^{1-}$ | $\boxed{NH_4ClO_3}$ |
| $Sn^{4+}$ | and | $SO_4^{2-}$ | $\boxed{Sn(SO_4)_2}$ |
| $Fe^{3+}$ | and | $Cr_2O_7^{2-}$ | $\boxed{Fe_2(Cr_2O_7)_3}$ |
| $NH_4^{1+}$ | and | $N^{3-}$ | $\boxed{(NH_4)_3N}$ |

## Inorganic Nomenclature

- ***Ionic Compounds (cation/anion combos)***

Single-Charge Cations with Elemental Anions

The single-charge cations are:

groups 1, 2, 13, and $Ag^{1+}$ and $Zn^{2+}$

A. To name, given the formula:

1. Use name of cation.
2. Use name of anion (it has the ending “ide”).

| | |
|---|---|
| NaF | sodium fluoride |
| BaO | barium oxide |
| $Na_2O$ | sodium oxide |
| $BaF_2$ | barium fluoride |

B. To write formula, given the name:

1. Write symbols for the two types of ions.
2. Balance charges to write formula.

| | | |
|---|---|---|
| silver sulfide | $Ag^{1+}$ $S^{2-}$ | $Ag_2S$ |
| zinc phosphide | $Zn^{2+}$ $P^{3-}$ | $Zn_3P_2$ |
| calcium iodide | $Ca^{2+}$ $I^{1-}$ | $CaI_2$ |

# Multiple-Charge Cations with Elemental Anions

The multiple-charge cations are: $Pb^{2+}/Pb^{4+}$, $Sn^{2+}/Sn^{4+}$, transition elements (not Ag or Zn)

A. To name, given the formula:

1. Figure out charge on cation.
2. Write name of cation.
3. Write Roman numerals in ( ) to show cation's charge.
4. Write name of anion.

Stock System of nomenclature

| | | |
|---|---|---|
| FeO | $Fe^{?}$ $O^{2-}$ | iron (II) oxide |
| $Fe_2O_3$ | 2 $Fe^{?}$ 3 $O^{2-}$ | iron (III) oxide |
| CuBr | $Cu^{?}$ $Br^{1-}$ | copper (I) bromide |
| $CuBr_2$ | $Cu^{?}$ 2 $Br^{1-}$ | copper (II) bromide |

B. To find the formula, given the name:

1. Write symbols for the two types of ions.
2. Balance charges to write formula.

| | | |
|---|---|---|
| cobalt (III) chloride | $Co^{3+}$ $Cl^{1-}$ | $CoCl_3$ |
| tin (IV) oxide | $Sn^{4+}$ $O^{2-}$ | $SnO_2$ |
| tin (II) oxide | $Sn^{2+}$ $O^{2-}$ | SnO |

# Traditional System of Nomenclature

…used historically (and still some today) to name compounds ʷ/multiple-charge cations

To use: 1. Use Latin root of cation.

2. Use ***-ic*** ending for higher charge;

“ ***-ous*** “ “ lower “

3. Then say name of anion, as usual.

| Element | Latin root | ***-ic*** | ***-ous*** |
|---|---|---|---|
| gold, Au | aur- | $Au^{3+}$ | $Au^{1+}$ |
| lead, Pb | plumb- | $Pb^{4+}$ | $Pb^{2+}$ |
| tin, Sn | stann- | $Sn^{4+}$ | $Sn^{2+}$ |
| copper, Cu | cupr- | $Cu^{2+}$ | $Cu^{1+}$ |
| iron, Fe | ferr- | $Fe^{3+}$ | $Fe^{2+}$ |

Write formulas:

cuprous sulfide

$Cu^{1+}$ $S^{2-}$ $\boxed{Cu_2S}$

auric nitride

$Au^{3+}$ $N^{3-}$ $\boxed{AuN}$

ferrous fluoride

$Fe^{2+}$ $F^{1-}$ $\boxed{FeF_2}$

Write names:

$Pb_3P_4$ 3 $Pb^{?}$ 4 $P^{3-}$

$\boxed{\text{plumbic phosphide}}$

$Pb_3P_2$ 3 $Pb^{?}$ 2 $P^{3-}$

$\boxed{\text{plumbous phosphide}}$

$SnCl_4$ $Sn^{?}$ 4 $Cl^{1-}$

$\boxed{\text{stannic chloride}}$

## Compounds Containing Polyatomic Ions

Insert name of ion where it should go

in the compound's name.

Write formulas:

| | | |
|---|---|---|
| iron (III) nitrite | $Fe^{3+}$ $NO_3^{1-}$ | $Fe(NO_3)_3$ |
| ammonium phosphide | $NH_4^{1+}$ $P^{3-}$ | $(NH_4)_3P$ |
| ammonium chlorite | $NH_4^{1+}$ $ClO_2^{1-}$ | $NH_4ClO_2$ |
| zinc phosphate | $Zn^{2+}$ $PO_4^{3-}$ | $Zn_3(PO_4)_2$ |
| lead (II) permanganate | $Pb^{2+}$ $MnO_4^{1-}$ | $Pb(MnO_4)_2$ |

Write names:

| | | |
|---|---|---|
| $(NH_4)_2S_2O_3$ | | ammonium thiosulfate |
| $AgBrO_3$ | | silver bromate |
| $(NH_4)_3N$ | | ammonium nitride |
| $U(CrO_4)_3$ | $U^{?}$ 3 $CrO_4^{2-}$ | uranium (VI) chromate |
| $Cr_2(SO_3)_3$ | 2 $Cr^{?}$ 3 $SO_3^{2-}$ | chromium (III) sulfite |

- ***Covalent Compounds***

-- contain two types of nonmetals

Key: FORGET CHARGES

What to do:

Use Greek prefixes to indicate how many atoms of each element, but don't use "mono" on first element.

| | |
|---|---|
| 1 – mono | 6 – hexa |
| 2 – di | 7 – hepta |
| 3 – tri | 8 – octa |
| 4 – tetra | 9 – nona |
| 5 – penta | 10 – deca |

EXAMPLES:

| | |
|---|---|
| carbon dioxide | $CO_2$ |
| CO | carbon monoxide |
| dinitrogen trioxide | $N_2O_3$ |
| $N_2O_5$ | dinitrogen pentoxide |
| carbon tetrachloride | $CCl_4$ |
| $NI_3$ | nitrogen triiodide |

- ***Acid Nomenclature***

binary acids: acids $^{w}$/H and one other element

**Binary Acid Nomenclature**

1. Write "hydro."
2. Write prefix of the other element, followed by "-ic acid."

| | |
|---|---|
| HF | hydrofluoric acid |
| HCl | hydrochloric acid |
| HBr | hydrobromic acid |
| hydroiodic acid | HI |
| hydrosulfuric acid | $H_2S$ |

oxyacids: acids containing H, O, and one other element

Common oxyanions (polyatomic ions that contain oxygen) that combine with H to make oxyacids:

| | |
|---|---|
| $BrO_3^{1-}$ | $NO_3^{1-}$ |
| $CO_3^{2-}$ | $PO_4^{3-}$ |
| $ClO_3^{1-}$ | $SO_4^{2-}$ |
| $IO_3^{1-}$ | |

## Oxyacid Nomenclature

Write prefix of oxyanion, followed by “-ic acid.”

| | |
|---|---|
| $HBrO_3$ | bromic acid |
| $HClO_3$ | chloric acid |
| $H_2CO_3$ | carbonic acid |
| sulfuric acid | $H_2SO_4$ |
| phosphoric acid | $H_3PO_4$ |

Above examples show “most common” forms of the oxyacids. If an oxyacid differs from the above by the # of O atoms, the name changes are as follows:

| | | |
|---|---|---|
| one more O | = | per_____ic acid |
| **“most common” # of O** | **=** | **_____ic acid** |
| one less O | = | _____ous acid |
| two fewer O | = | hypo_____ous acid |

| | |
|---|---|
| $HClO_4$ | perchloric acid |
| $HClO_3$ | chloric acid |
| $HClO_2$ | chlorous acid |
| $HClO$ | hypochlorous acid |
| phosphorous acid | $H_3PO_3$ |
| hypobromous acid | $HBrO$ |
| persulfuric acid | $H_2SO_5$ |

**Empirical Formula and Molecular Formula**

lowest-terms formula

shows the true number and type of atoms in a molecule

| Compound | Molecular Formula | Empirical Formula |
|---|---|---|
| glucose | $C_6H_{12}O_6$ | $CH_2O$ |
| propane | $C_3H_8$ | $C_3H_8$ |
| butane | $C_4H_{10}$ | $C_2H_5$ |
| naphthalene | $C_{10}H_8$ | $C_5H_4$ |
| sucrose | $C_{12}H_{22}O_{11}$ | $C_{12}H_{22}O_{11}$ |
| octane | $C_8H_{18}$ | $C_4H_9$ |